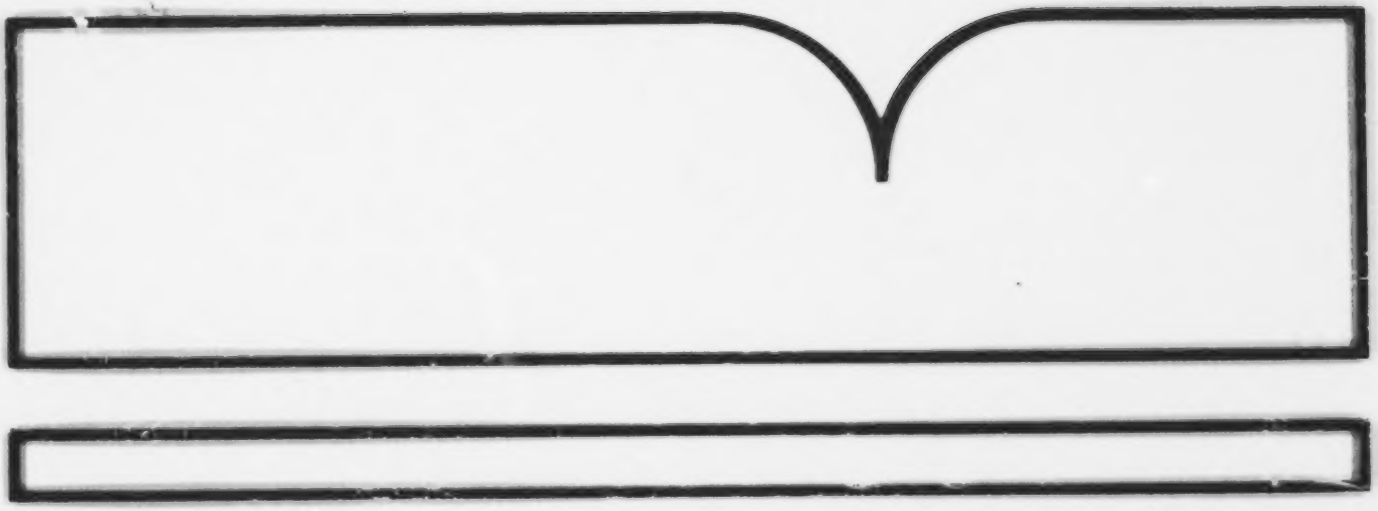
PB89-203715

Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Particulate Matter (PM) Emission Standards for Small Steam Generating Units

(U.S.) Environmental Protection Agency, Research Triangle Park, NC

May 89



U.S. Department of Commerce
National Technical Information Service
NTIS

PB89-203715

United States
Environmental Protection
Agency

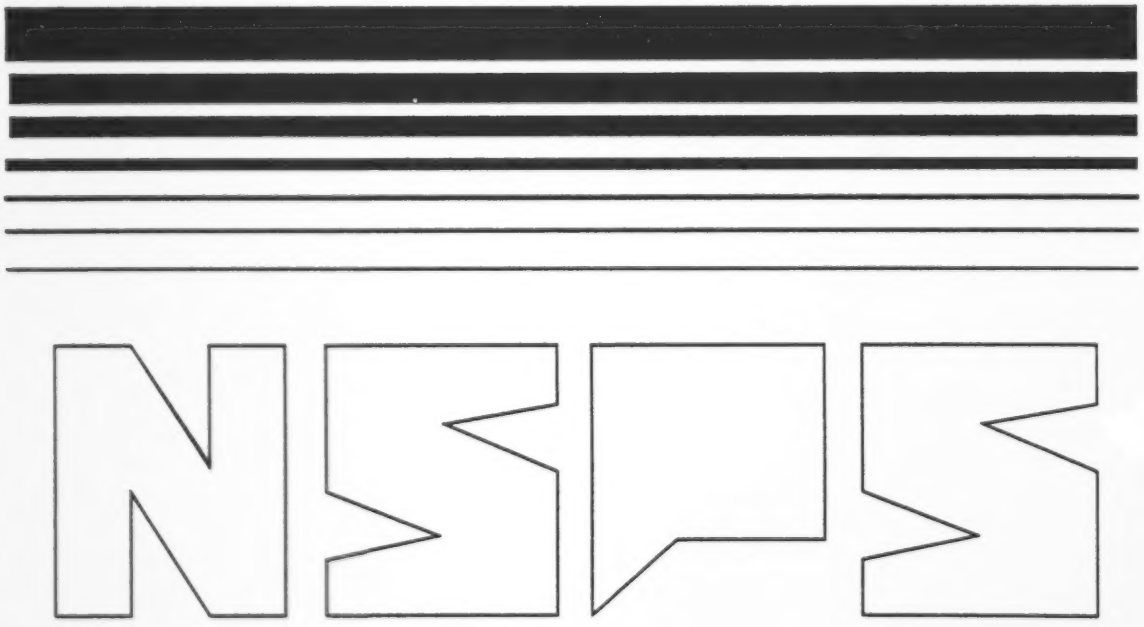
Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-89-11
May 1989

Air

EPA

Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Particulate Matter (PM) Emission Standards for Small Steam Generating Units



REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

EPA-450/3-89-11

OVERVIEW OF THE REGULATORY BASELINE, TECHNICAL BASIS, AND ALTERNATIVE CONTROL LEVELS FOR PARTICULATE MATTER (PM) EMISSION STANDARDS FOR SMALL STEAM GENERATING UNITS

Emission Standards Division

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, N.C. 27711

May 1989

This report has been reviewed by the Emission Standards Division of the Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation of use. Copies of the report are available through the Library Service Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711, or from National Technical Services, 5285 Port Royal Road, Springfield, Virginia 22161.

TABLE OF CONTENTS

Section		Page
1.0	INTRODUCTION	1
2.0	SUMMARY	2
3.0	OIL PM EMISSIONS AND CONTROL TECHNIQUES	6
	3.1 REGULATORY BASELINE EMISSION LEVEL	6
	3.2 MEDIUM AND VERY LOW SULFUR/LOW ASH OIL	7
	3.3 WET FLUE GAS DESULFURIZATION SYSTEMS	8
	3.4 ELECTROSTATIC PRECIPITATORS	10
	3.5 ALTERNATIVE CONTROL LEVELS	10
4.0	COAL PM EMISSIONS AND CONTROL TECHNIQUES	14
	4.1 REGULATORY BASELINE EMISSION LEVEL	14
	4.2 DOUBLE MECHANICAL COLLECTORS	15
	4.3 SIDESTREAM SEPARATORS	16
	4.4 WET FLUE GAS DESULFURIZATION SYSTEMS	18
	4.5 FABRIC FILTERS	18
	4.6 ELECTROSTATIC PRECIPITATORS	21
	4.7 ALTERNATIVE CONTROL LEVELS	23
5.0	WOOD PM EMISSIONS AND CONTROL TECHNIQUES	25
	5.1 REGULATORY BASELINE EMISSION LEVEL	25
	5.2 DOUBLE MECHANICAL COLLECTORS	25
	5.3 WET SCRUBBERS	26
	5.4 ELECTROSTATIC PRECIPITATORS	28
	5.5 ALTERNATIVE CONTROL LEVELS	28
6.0	REFERENCES	30

LIST OF TABLES

Tables		Page
2-1	SO_2 ALTERNATIVE CONTROL LEVELS FOR SMALL OIL- AND COAL-FIRED BOILERS	3
2-2	PM ALTERNATIVE CONTROL LEVELS FOR SMALL OIL-, COAL-, AND WOOD-FIRED BOILERS	4
3-1	PARTICULATE EMISSIONS FROM SO_2 WET SCRUBBERS APPLIED TO RESIDUAL OIL-FIRED BOILERS	9
3-2	SUMMARY OF PARTICULATE EMISSION TEST DATA FOR ELECTROSTATIC PRECIPITATORS APPLIED TO OIL-FIRED BOILERS	11
4-1	PM EMISSIONS DATA FOR SIDESTREAM SEPARATORS APPLIED TO SMALL COAL-FIRED BOILERS	17
4-2	PM EMISSIONS DATA FOR WET SCRUBBERS APPLIED TO COAL-FIRED BOILERS	19
4-3	PM EMISSIONS DATA FOR FABRIC FILTERS APPLIED TO COAL-FIRED BOILERS	20
4-4	PM EMISSIONS DATA FOR ELECTROSTATIC PRECIPITATORS APPLIED TO COAL-FIRED BOILERS	22
5-1	PM EMISSIONS DATA FOR WET SCRUBBERS APPLIED TO WOOD-FIRED BOILERS	27
5-2	SUMMARY OF PARTICULATE EMISSION TEST DATA ON WOOD-FIRED BOILERS CONTROLLED WITH ESPS AND EGBS	29

1.0 INTRODUCTION

This report provides an overview of the regulatory baseline, technical basis, and alternative control levels available for developing new source performance standards (NSPS) limiting particulate matter (PM) emissions from small steam generating units (i.e., boilers). Small boilers are defined as industrial-commercial-institutional steam generating units having heat input capacities of 29 MW (100 million Btu/hour) or less.

Many PM control techniques were considered for the purpose of evaluating alternative PM emission standards for small boilers. Detailed discussions of the design and operating principles of these techniques can be found in the report entitled "Small Steam Generating Unit Characteristics and Emission Control Techniques,"[1] and References 2 and 3.

This report discusses the quantity of PM emissions generated and the technical feasibility of controlling those emissions from boilers with heat input capacities of 29 MW (100 million Btu/hour) and less. The uncontrolled PM emissions from the combustion of natural gas in small steam generating units are very low. Uncontrolled PM emission levels of less than 9 ng/J (0.02 lb/million Btu) heat input are typical of natural gas-fired steam generating units. Because of these low uncontrolled PM emission levels, the application of any type of PM control technology to small natural gas-fired steam generating units would result in unreasonable costs for little or no air quality benefit. Consequently, no further consideration was given to the development of standards to limit PM emissions from natural gas-fired units.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/3-89-11	2.	3. RECIPIENT'S ACCESSION NO. PB89 203715/AS
4. TITLE AND SUBTITLE Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Particulate Matter (PM) Emission standards for Small Steam Generating Units.		5. REPORT DATE May 1989 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Emission Standards Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-4378
12. SPONSORING AGENCY NAME AND ADDRESS Office of Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/200/04

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report provides a summary of the technical data used in developing proposed new source performance standards (NSPS) for small industrial-commercial-institutional steam generating units (small boilers). The report focuses on particulate matter (PM) emissions from boilers firing coal, oil, and wood with heat input capacities of 100 million Btu/hour or less. Conclusions are drawn from the data regarding the performance of technologies available to reduce PM emissions. Alternative control levels are then chosen based on the conclusions drawn from the data.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Pollution Control Standards of Performance Steam Generating Units	Industrial Boilers Small Boilers Air Pollution Control	

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 38
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE PC $13.95/A3 $6.95

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

2.0 SUMMARY

Particulate matter emissions from oil combustion may be correlated with oil sulfur content. Such correlations indicate that reductions in PM emissions are a secondary benefit associated with reducing emissions of SO_2 through the combustion of low sulfur oils. Unlike oil, PM emissions from coal cannot be correlated to fuel sulfur content. As a result, limiting SO_2 emissions from coal combustion through the use of low sulfur coal has no effect on PM emissions. The use of flue gas desulfurization (FGD) systems to limit SO_2 emissions from oil and coal combustors, however, also results in reduced PM emissions.

Consequently, alternative control levels for standards limiting SO_2 emissions from oil and coal combustion can result in reductions in PM emissions. In focusing on alternative control levels for standards limiting PM emissions from oil and coal combustion, therefore, any reduction in PM emissions associated with alternative control levels for standards limiting SO_2 emissions should be taken into account. Thus, alternative control levels for standards limiting PM emissions from oil and coal combustion are considered in relation to alternative control levels for standards limiting SO_2 emissions.

Wood, unlike oil and coal, contains little or no sulfur. In addition, few, if any, mixed fuel-fired (i.e., coal/wood or oil/wood) boilers are expected for this source category. As a result, there is no need to consider levels selected for SO_2 standards in considering alternative control levels for standards limiting PM emissions from small wood-fired boilers.

The alternative control levels considered for standards limiting SO_2 emissions from small oil- and coal-fired boilers are presented in Table 2-1. The alternative control levels selected in this study for standards limiting PM emissions from small oil-, coal-, and wood-fired boilers are presented in Table 2-2.

TABLE 2-1. SO_2 ALTERNATIVE CONTROL LEVELS FOR SMALL OIL- AND COAL-FIRED BOILERS

	SO_2 Emission Standard	Basis
Oil-Fired Boilers		
Regulatory baseline	1,290 ng/J (3.0 lb/million Btu)	High sulfur oil
Alternative Control Level 1	690 ng/J (1.60 lb/million Btu)	Medium sulfur oil
Alternative Control Level 2	210 ng/J (0.50 lb/million Btu)	Very low sulfur oil
Alternative Control Level 3	90% SO_2 reduction	FGD
Coal-Fired Boilers		
Regulatory baseline	1,550 ng/J (3.6 lb/million Btu)	Medium sulfur coal[a]
Alternative Control Level 1	520 ng/J (1.2 lb/million Btu)	Low sulfur coal[b]
Alternative Control Level 2	90% SO_2 reduction	FGD or FBC[c]

[a]Type F - bituminous

[b]Type B - bituminous

[c]FGD = Flue Gas Desulfurization
FBC = Fluidized Bed Combustion

SOURCE: Reference 4.

TABLE 2-2. PM ALTERNATIVE CONTROL LEVELS FOR SMALL OIL-, COAL-, AND WOOD-FIRED BOILERS

	PM Emission Standard	Basis[a]
Oil-Fired Boilers		
Regulatory Baseline	95 ng/J (0.22 lb/million Btu)	HSO
Alternative Control Level A	73 ng/J (0.17 lb/million Btu)	MSO
Alternative Control Level B	43 ng/J (0.10 lb/million Btu)	WS or VLSO
Alternative Control Level C	22 ng/J (0.05 lb/million Btu)	ESP
Coal-Fired Boilers		
Regulatory Baseline		
< 8.7 MW (30 million Btu/hour)	190 ng/J (0.45 lb/million Btu)	SMC
≥ 8.7 MW (30 million Btu/hour)	260 ng/J (0.60 lb/million Btu)	SMC
Alternative Control Level A	130 ng/J (0.30 lb/million Btu)	DMC
Alternative Control Level B	86 ng/J (0.20 lb/million Btu)	SSS
Alternative Control Level C	43 ng/J (0.10 lb/million Btu)	SMC+WS
Alternative Control Level D	22 ng/J (0.05 lb/million Btu)	FF or SMC+ESP

TABLE 2-2. PM ALTERNATIVE CONTROL LEVELS FOR SMALL OIL-, COAL-, AND WOOD-FIRED BOILERS (continued)

	PM Emission Standard	Basis[a]
Wood-Fired Boilers		
Regulatory Baseline		
< 8.7 MW (30 million Btu/hour)	190 ng/J (0.45 lb/million Btu)	SMC
≥ 8.7 MW (30 million Btu/hour)	260 ng/J (0.60 lb/million Btu)	SMC
Alternative Control Level A	130 ng/J (0.30 lb/million Btu)	DMC
Alternative Control Level B	86 ng/J (0.20 lb/million Btu)	SMC + WS (low pressure drop)
Alternative Control Level C	43 ng/J (0.10 lb/million Btu)	SMC + ESP or SMC + WS (medium pressure drop)

[a] SMC = Single Mechanical Collector
DMC = Double Mechanical Collector
SSS = Sidestream Separator
FF = Fabric Filter
ESP = Electrostatic Precipitator
WS = Wet Flue Gas Desulfurization System (or Wet Scrubber)
HSO = High Sulfur Oil
MSO = Medium Sulfur Oil
VLSO = Very Low Sulfur Oil

3.0 OIL PM EMISSIONS AND CONTROL TECHNIQUES

Particulate matter emissions from oil combustion may be correlated with oil sulfur content.[5] Such correlations indicate that reductions in PM emissions are a secondary benefit associated with reducing emissions of SO_2 through the combustion of low sulfur oils. Particulate matter emissions are also reduced if FGD systems are used to reduce SO_2 emissions from oil combustion.[6] As a result, standards limiting SO_2 emissions from oil combustion, either through combustion of low sulfur oils or the use of FGD systems, result in reductions in PM emissions.

In considering alternative control levels for standards to limit PM emissions from oil combustion, the reductions in PM emissions associated with alternative control levels for standards limiting SO_2 emissions from oil combustion should be taken into account. In focusing on alternative control levels for PM standards, therefore, this report considers these alternatives in relation to alternative control levels selected for SO_2 standards.

The emission control techniques considered for limiting PM emissions from small oil-fired boilers were medium and very low sulfur/low ash oils, wet FGD systems or wet scrubbers, and ESP's. Fabric filters were not considered because of the sticky nature of fly ash from oil combustion. Mechanical collectors were not evaluated for oil-fired boiler applications because they are considered ineffective in collecting the small particle size of PM from oil firing.

3.1 REGULATORY BASELINE EMISSION LEVEL

The regulatory baseline emission level is defined as the emission level that new small boilers would be required to meet under existing State implementation plans (SIP). The national average SIP PM emission limits for small oil-fired boilers range from 130 to 190 ng/J (0.30 to 0.45 lb/million Btu), depending on boiler size.[7] These emission limits can generally be met when firing high sulfur oil with no add-on controls.

This is consistent with the regulatory baseline selected for assessing alternative control levels for standards limiting SO_2 emissions from small oil-fired boilers. As discussed in Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Sulfur Dioxide (SO_2) Emission Standards for Small Steam Generating Units, the regulatory baseline selected for small oil-fired boilers corresponds to the firing of high sulfur oil [with a sulfur content of 1,290 ng SO_2/J (3.0 lb SO_2/million Btu)].[8]

A review of the data from over 100 steam generating units that were used to establish the correlation between fuel oil sulfur content and emissions of PM from oil combustion presented in the manual, Compilation of Air Pollutant Emission Factors (AP-42), indicates that fuel oils having a sulfur content of 1,290 ng SO_2/J (3.0 lb SO_2/million Btu) would be expected to produce PM emissions at a rate of about 95 ng PM/J (0.22 lb PM/million Btu).[9] Consequently, 95 ng PM/J (0.22 lb PM/million Btu) is selected as the regulatory baseline for small oil-fired boilers.

3.2 MEDIUM AND VERY LOW SULFUR/LOW ASH OIL

As discussed in Reference 4, the use of medium and very low sulfur oil serves as the basis for Alternative Control Levels 1 and 2 for standards limiting SO_2 emissions from small oil-fired boilers, respectively. Alternative Control Level 1 is 690 ng SO_2/J (1.60 lb SO_2/million Btu) based on the firing of medium sulfur oil. Alternative Control Level 2 is 210 ng SO_2/J (0.50 lb SO_2/million Btu) based on the firing of very low sulfur oil.

Emission test data were collected using Reference Method 5 from 18 steam generating units with heat input capacities ranging from 28 to 400 MW (94 to 1,360 million Btu/hour).[10] When combusting fuel oils with a sulfur content of 690 ng SO_2/J (1.60 lb SO_2/million Btu) or less, the PM emissions were less than 73 ng/J (0.17 lb/million Btu) heat input. In addition, based on the data from AP-42 discussed above, combustion of oil with a sulfur content of 690 ng SO_2/J (1.60 lb SO_2/million Btu) or less will produce PM emissions of 56 ng/J (0.13 lb/million Btu) or less.

Emission test data presented in Reference 11 indicate that firing oil with a sulfur content of 210 ng SO_2/J (0.50 lb SO_2/million Btu) or less will generate PM emissions of 43 ng/J (0.10 lb/million Btu) or less. Based on the data from AP-42 discussed above, combustion of oil with a sulfur content of 210 ng SO_2/J (0.50 lb SO_2/million Btu) or less will produce PM emissions of 23 ng/J (0.054 lb/million Btu) or less.

Thus, firing medium sulfur oil (690 ng SO_2/J [1.60 lb SO_2/million Btu]) will reduce PM emissions from small boilers to 73 ng/J (0.17 lb/million Btu) or less. Similarly, firing very low sulfur oil [210 ng SO_2/J (0.50 lb SO_2/million Btu)] will reduce PM emissions to 43 ng/J (0.10 lb/million Btu) or less.

3.3 WET FLUE GAS DESULFURIZATION SYSTEMS (WET SCRUBBERS)

As discussed in Reference 4, the use of wet FGD systems serves as the basis for Alternative Control Level 3 for standards limiting SO_2 emissions from small oil-fired boilers. Table 3-1 presents a summary of PM emissions data collected from small oil-fired boilers controlled by wet FGD systems. The boilers ranged in size from 7 to 17 MW (22 to 57 million Btu/hour) and burned oil with sulfur contents ranging from 1.1 to 2.8 weight percent. During the tests, the boilers operated at 70 to 106 percent of full load. Measured SO_2 removal efficiencies for the scrubbers ranged from 85 to 99 percent.

Particulate matter emissions from these FGD systems ranged from 13 to 56 ng/J (0.03 to 0.13 lb/million Btu). For 17 of the 18 tests, emissions ranged from 13 to 43 ng/J (0.03 to 0.10 lb/million Btu). Only one test resulted in PM emissions greater than 43 ng/J (0.10 lb/million Btu); this test was conducted on a boiler operating at a load in excess of design capacity. This test result, therefore, is not considered to be representative of PM emissions from FGD systems operating under normal conditions.

All FGD systems listed above are wet scrubbers designed with a venturi apparatus for PM control. Therefore, wet FGD systems or wet scrubbers are considered to be a demonstrated control technique for reducing PM emissions from small oil-fired boilers to 43 ng/J (0.10 lb/million Btu) or less.

TABLE 3-1. PARTICULATE EMISSIONS FROM SO2 WET SCRUBBERS APPLIED TO RESIDUAL OIL-FIRED BOILERS (12)

Company	Number of units	Boiler capacity, MW (million Btu/hr) heat input	Scrubber type	Design particulate control efficiency (%)	Fuel sulfur (wt. %)	SO2 removal (%)	Test load (percent of design capacity)	Controlled particulate emissions (lb/million Btu) (a)
Chevron	7	15 (52) (b)	VS	40	1.10	92.0	NA	0.03
Gen A-1, Run 1	1	17 (57)	SV	91	1.10	99.0	86	0.04
Gen A-1, Run 3	1	17 (57)	SV	92	1.10	99.0	83	0.04
Gen A-1, Run 5	1	17 (57)	SV	76	1.10	99.0	70	0.06
Gen A-1, Run 6	1	17 (57)	SV	70	1.10	99.9	80	0.07
Gen C-50, Run 1	1	17 (57)	SV	89	2.80	99.9	104	0.06
Gen C-50, Run 3	1	17 (57)	SV	77	2.80	99.9	106	0.13
Union #12, Run 1	1	15 (50)	HT	40	1.65	95	92	0.08
Union #12, Run 2	1	15 (50)	HT	40	1.65	95	90	0.08
Union #23, Run 1	1	7 (25)	Koch	40	1.46	98	91	0.10
Union #23, Run 2	1	7 (25)	Koch	40	1.46	98	92	0.06
Union #24, Run 1	1	15 (50)	And	40	1.46	96	87	0.07
	1	15 (50)	And	40	1.46	96	84	0.09
Union #30, Run 1	1	15 (50)	HT	40	1.34	92	90	0.09
	1	15 (50)	HT	40	1.34	92	92	0.09
Union #33, 37, Run 2	5	15 (50)	Koch	40	1.14	99	90	0.06
Union #33, 37, Run 4	5	15 (50)	Koch	40	1.14	99	90	0.07
Union #33, 37, Run 6	5	15 (50)	Koch	40	1.14	99	89	0.06

NA = Not available.
VS = Venturi Scrubber.
SV = Steam Venturi Eductor with Spray Tower.
HT = Heater Tech. Caustic Scrubber, Venturi.
Koch = Koch Caustic Scrubber, Tray Tower (3 trays).
And = Anderson 2000 Caustic Scrubber, Spray Baffle.

(a) Based on EPA Reference Method 5 (front half catch). Multiply lb/million Btu by 430 for conversion to ng/J.
(b) Test load heat input.

3.4 ELECTROSTATIC PRECIPITATORS

Most of the PM emissions data available for ESPs applied to oil-fired boilers were gathered in a study of utility boilers, but the technology is directly transferable to small oil-fired boilers.[13] Electrostatic precipitator performance depends primarily on the specific collection area (SCA), which is the ratio of the total collection plate area to the volumetric gas flow rate. Because this parameter is a ratio, its correlation to ESP performance is independent of boiler size; therefore, data for ESPs on utility oil-fired boilers are representative of ESP performance on small oil-fired boilers.

Table 3-2 summarizes PM emissions data for ESPs applied to oil-fired boilers. During the tests, oils with sulfur contents ranging from 0.7 to 2.0 weight percent were fired. The PM emissions ranged from 18 to 29 ng/J (0.04 to 0.07 lb/million Btu). Information regarding SCA was available for only one ESP listed in Table 3-2. This unit had an SCA of 435 $m^2/1{,}000m^3/s$ (133 $ft^2/1{,}000$ acfm) and serviced a boiler firing a 2.0 weight percent sulfur oil. During the test, PM emissions ranged from 18 to 21 ng/J (0.041 to 0.049 lb/million Btu). The performance of the other units could not be evaluated because their SCAs are not available.

These data, however, indicate that an ESP with an SCA of at least 435 $m^2/1{,}000m^3/s$ (133 $ft^2/1{,}000$ acfm) is capable of reducing PM emissions from small oil-fired boilers to 22 ng/J (0.05 lb/million Btu) or less. Therefore, ESPs are considered to be a demonstrated control technique for reducing PM emissions from small oil-fired boilers to 22 ng/J (0.05 lb/million Btu) or less.

3.5 ALTERNATIVE CONTROL LEVELS

As mentioned above, alternative control levels for standards limiting SO_2 emissions from oil-fired boilers will achieve PM emission reductions. Thus, alternative control levels considered for standards limiting PM emissions from small oil-fired boilers should be discussed in relation to alternative control levels for standards limiting SO_2 emissions.

TABLE 3-2. SUMMARY OF PARTICULATE EMISSION TEST DATA FOR ELECTROSTATIC PRECIPITATORS APPLIED TO OIL-FIRED BOILERS (14)

Company	Number of units	Boiler capacity, MW (million Btu/hr) heat input	Filterable particulate emissions (lb/million Btu) (a)	Particulate control efficiency (%)	Fuel		Test load, MW (million Btu/hr) heat input
					(% sulfur)	(% ash)	
Polaroid Corp. New Bedford	2	28 (94)	0.055 0.070	40 51	0.7 0.7	NA (c) NA	NA NA
Boston Edison (b) Mystic Station Unit No. 7	1	1610 (5500)	0.041 (d) (0.012) (d)	83 (e) NA	2.0 2.0	0.08 0.08	1630 (5580)
	1	1610 (5500)	0.045 (d) (0.009) (d)	69 (e) NA	2.0 2.0	0.09 0.09	1640 (5590)
	1	1610 (5500)	0.049 (d) (0.014) (d)	78 (e) NA	2.0 2.0	0.10 0.10	1610 (5490)
Hartford Electric Light Co. Middletown Station	1	328 (1120)	0.070	NA	1.95 (f)	0.09	NA
	1	322 (1100)	0.057	NA	1.86 (f)	0.07	NA
	1	328 (1120)	0.067	NA	1.79 (f)	0.07	NA

(a) Multiply lb/million Btu by 430 for conversion to ng/J.

(b) Design SCA is 435 square meters per 1000 cubic meters per second (133 square feet per 1000 ACFM). The ESP is a cold-side unit controlling a high sulfur, high vanadium residual oil.

(c) NA = Not available.

(d) Data collected with EPA Method 5 train with filter temperature of about 320 degrees F; following collection, filters were baked per EPA Method 5B; results in parentheses are EPA Method 5B results.

(e) Efficiency calculation based on low temperature EPA Method 5 inlet and outlet data.

(f) Oil additives used to prevent boiler fouling and corrosion.

Alternative Control Level 1 for SO_2 is 690 ng/J (1.60 lb /million Btu) based on the firing of medium sulfur oil. As discussed in Section 3.2, this corresponds to PM emissions of 73 ng/J (0.17 lb/million Btu) or less. Particulate matter emissions could be reduced to a level of 43 ng/J (0.10 lb/million Btu) or less by applying a wet scrubber or by firing very low sulfur oil. Emissions of PM could be further reduced to a level of 22 ng/J (0.05 lb/million Btu) by applying an ESP.

Alternative Control Level 2 for SO_2 is 210 ng/J (0.50 lb/million Btu) based on the firing of very low sulfur oil. As discussed above, the combustion of very low sulfur oil corresponds to PM emissions of 43 ng/J (0.10 lb/million Btu) or less. Emission of PM could be reduced to 22 ng/J (0.05) lb/million Btu) by applying an ESP.

Alternative Control Level 3 for SO_2 is 90 percent SO_2 emission reduction based on the use of FGD systems. As discussed in Section 3.3, FGD systems on small oil-fired boilers can reduce PM emissions to 43 ng/J (0.10 lb/million Btu) or less. Further PM emission reductions could be achieved, to a level of 22 ng/J (0.05 lb/million Btu), by applying an ESP upstream of the FGD system.

As a result, an emission rate of 73 ng/J (0.17 lb/million Btu) is selected as Alternative Control Level A for standards limiting PM emissions from small oil-fired boilers. This alternative control level, however, is achieved as a secondary benefit of Alternative Control Level 1 for standards limiting SO_2 emissions and would, in fact, impose no additional emission control requirements.

An emission rate of 43 ng/J (0.10 lb/million Btu) is selected as Alternative Control Level B for standards limiting PM emissions. This alternative is based on application of wet scrubbers or wet FGD systems or the firing of very low sulfur oil. This alternative control level would impose additional emission control requirements beyond those imposed by Alternative Control Level 1 for standards limiting SO_2 emissions. It would not, however, impose any additional emission control requirements beyond those imposed by Alternative Control Levels 2 and 3 for standards limiting SO_2 emissions.

An emission rate of 22 ng/J (0.05 lb/million Btu) based on the use of an ESP is selected as Alternative Control Level C for standards limiting PM emissions. This alternative control level would impose additional emission control requirement beyond those imposed by Alternative Control Levels 1, 2, and 3 for standards limiting SO_2 emissions.

4.0 COAL PM EMISSIONS AND CONTROL TECHNIQUES

Unlike oil, PM emissions from coal cannot be correlated to fuel sulfur content. As a result, limiting SO_2 emissions from coal combustion through the use of low sulfur coal has little, if any, effect on PM emissions. The use of FGD systems to limit SO_2 emissions from coal combustion, however, does result in reduced PM emissions.

Consequently, alternative control levels for standards limiting SO_2 emissions from coal combustion can also result in reductions in PM emissions. In focusing on alternative control levels for standards limiting PM emissions from coal combustion, therefore, any reduction in PM emissions associated with alternative control levels for standards limiting SO_2 emissions should be taken into account. Thus, as with oil, alternative control levels for standards limiting PM emissions from coal combustion are considered in relation to alternative control levels for standards limiting SO_2 emissions.

The emission control techniques considered for limiting PM emissions from small coal-fired boilers include double mechanical collectors, sidestream separators, wet FGD systems or wet scrubbers, fabric filters, and ESPs.

4.1 REGULATORY BASELINE EMISSION LEVEL

The national average SIP emission limits for PM emissions from coal-fired boilers range from 140 to 200 ng/J (0.33 to 0.46 lb/million Btu). The PM control system typically used to meet these emission limits is a single mechanical collector. Mechanical collection is a well-established technology using centrifugal separation to remove particles from a gas stream. Mechanical collectors have been widely used for years to control PM emissions from steam generating units firing coal. More recently, they have been used as flue gas precleaning devices located upstream of more efficient PM control devices.

Based on emissions test data in Reference 3, however, single mechanical collectors are unable to maintain these low emission levels over time. With

time, single mechanical collector performance deteriorates and PM emissions increase. The test data in Reference 3 indicate that emission levels of 260 ng/J (0.60 lb/million Btu) for spreader stokers and 190 ng/J (0.45 lb/million Btu) for underfeed stoker coal-fired boilers are more representative of long-term mechanical collector performance on these boiler types. Underfeed stokers are predominant in the 2.9 to 8.7 MW (10 to 30 million Btu/hour) size range while spreader stokers are most prevalent above this size range. Thus, regulatory baseline PM emission levels of 190 ng/J (0.45 lb/ million Btu) and 260 ng/J (0.60 lb/million Btu) were selected for small coal-fired boilers of less than 8.7 MW (30 million Btu/hour) and greater than or equal to 8.7 MW (30 million Btu/hour), respectively.

4.2 DOUBLE MECHANICAL COLLECTORS

Most mechanical collectors consist of multiple small cyclone collectors connected in a parallel arrangement (multitube cyclone). A variation of this technology consists of two mechanical collectors connected in series. This latter configuration is referred to as a double mechanical collector (DMC). This arrangement typically achieves lower PM emission levels than a single mechanical collector.

Although double mechanical collectors will reduce PM emissions from coal combustion, they are relatively ineffective for collection of PM with mean diameters smaller than 10 microns (PM_{10}). These particle sizes, however, are in the inhalable range and have the greatest potential for adverse health impacts.

To maintain the collection efficiency of double mechanical collectors, regular maintenance is required.[15] This is because the performance of mechanical collectors generally deteriorates with age due to potential air leakage into the ductwork and erosion of the internal structure by abrasive fly ash. Air leakage and erosion of internal structures tend to disturb the cyclonic flow pattern, which is vital to double mechanical collector performance. Air leakage may also cause re-entrainment of PM previously collected. In both cases, the PM control performance is significantly

reduced. As a result, annual emission tests together with repairs or maintenance are necessary to ensure optimum double mechanical collector performance over time.

To assess the performance of double mechanical collectors on coal-fired boilers, PM emissions data from nine sites were reviewed.[16] These data were gathered using EPA Method 5 procedures. The boilers ranged in size from 15 to 60 MW (60 to 206 million Btu/hour) and were operated at 33 to 100 percent of full load during the tests. Analyses of the coal fired in seven of these boilers showed ash contents ranging from 4.8 to 9.5 weight percent and sulfur contents ranging from 470 to 600 ng SO_2/J (1.1 to 1.4 lb SO_2/million Btu). Fuel analyses were not available for the remaining two sites. The average PM emissions ranged from 77 to 130 ng/J (0.18 to 0.29 lb/million Btu). Thus, double mechanical collectors are considered to be a demonstrated control technique for reducing PM emissions from boilers firing low sulfur coal to 130 ng/J (0.30 lb/million Btu) or less. However, the boiler owner/operator must limit the ash content of the coal fired to approximately 10 weight percent or less.

4.3 SIDESTREAM SEPARATORS

A sidestream separator is a mechanical collector from which a slipstream or "sidestream" of flue gas is routed to a small fabric filter. In most cases, about 20 percent of the total flue gas volume passes through the fabric filter, although in some cases it may approach 50 percent of the total gas stream. Because a sidestream separator includes a mechanical collector, the same potential exists for deterioration of performance with age, as discussed for double mechanical collectors in Section 4.2. Thus, regular maintenance and annual emissions testing are required to ensure optimum PM control performance.

Table 4-1 presents PM emissions data from eight stoker boilers ranging in size from 9 to 29 MW (31 to 100 million Btu/hour) and retrofitted with sidestream separators. The boilers operated at loads ranging from 68 to 108 percent of full capacity under relatively constant load conditions. The percent of total flow sent to the baghouse varied from 15 to 51 percent. Coal ash content ranged from 4.3 to 10.1 weight percent. Particulate matter

TABLE 4-1. PM EMISSIONS DATA FOR SIDE STREAM SEPARATORS APPLIED TO SMALL COAL-FIRED BOILERS (17)

Plant	Boiler capacity, MW (million Btu/hr) heat input	Fuel			Test load range (percent of design capacity)	Boiler type (b)	Controlled particulate emissions (lb/million Btu) (c)	Percent of flow to baghouse
		percent ash	percent sulfur	heating value (Btu/lb) (a)				
Gen Motors (DDD)	15 (50)	9.7	0.8	12,900	68	SS	0.120	16
Gen Motors (EEE-1)	15 (50)	9.0	1.8	12,400	84-93	SS	0.120	37
Gen Motors (GGG)	20 (70)	4.3	0.9	13,700	78-80	SS	0.120	30
Gen Motors (CCC)	23 (80)	10.1	0.8	11,400	71-80	SS	0.130	31
Gen Motors (EEE-3)	18 (60)	8.8	2.1	12,400	99-105	SS	0.142	51
Gen Motors (BBB-3)	18 (60)	7.8	0.8	13,100	97-108	SS	0.165	17
Gen Motors (FFF)	29 (100)	6.1	1.7	13,100	85-97	SS	0.156	15
Milliken & Co.	9 (31)	7.8	1.3	13,200	100	SS	0.120	NA (d)

(a) Multiply Btu/lb by 2.323 for conversion to kJ/kg.
(b) SS = Spreader stoker.
(c) Multiply lb/million Btu by 430 for conversion to ng/J.
(d) NA = Not available.

emissions ranged from 52 to 73 ng/J (0.12 to 0.17 lb/million Btu). Therefore, sidestream separators are considered to be a demonstrated control technique for reducing PM emissions from small coal-fired boilers to 86 ng/J (0.20 lb/million Btu) or less. However, as discussed above for dual mechanical collectors, the boiler owner/operator must limit the ash content of the coal fired to approximately 10 weight percent or less.

4.4 WET FLUE GAS DESULFURIZATION SYSTEMS (WET SCRUBBERS)

Emission tests, summarized in Table 4-2, were available for three wet FGD systems servicing coal-fired spreader stoker boilers.[18] The boilers ranged from 37 to 69 MW (125 to 236 million Btu/hour) heat input and were operated at loads ranging from 73 to 92 percent of full load during the tests.

All three wet scrubbers were dual alkali FGD systems designed with venturi devices for combined PM and SO_2 control and were preceded by mechanical collectors. The scrubbers were operated at pressure drops ranging from 1.9 to 4.8 kPa (7.5 to 19.3 inches of water). The coals fired during the tests had ash contents ranging from 4.4 to 11.4 weight percent and sulfur contents ranging from 950 to 1,900 ng SO_2/J (2.2 to 4.4 lb SO_2/million Btu). The tests were conducted according to EPA Method 5 with high sample box temperatures. Particulate matter emissions ranged from 30 to 43 ng/J (0.07 to 0.10 lb/million Btu). Therefore, wet FGD systems or wet scrubbers are considered to be a demonstrated control technique for reducing PM emissions from small coal-fired boilers to 43 ng/J (0.10 lb/million Btu) or less.

4.5 FABRIC FILTERS

Table 4-3 presents PM emissions test data, boiler size, and fuel specifications for five coal-fired boilers and two fluidized bed combustion (FBC) units equipped with fabric filters. These data show PM emissions from fabric filters ranging from 4.1 to 15 ng/J (0.010 to 0.035 lb/million Btu). The boilers ranged in size from 13 to 59 MW (48 to 208 million Btu/hour) and were operated at loads ranging from 71 to 100 percent of full capacity. For

TABLE 4-2. PM EMISSIONS DATA FOR WET SCRUBBERS APPLIED TO COAL-FIRED BOILERS (18)

Site	Boiler capacity, MW (million Btu/hr) heat input	Scrubber type (a)	Operating pressure drop, kPa (inches water)	Boiler load (%)	Coal sulfur content (wt. %)	Coal ash content (wt. %)	Controlled particulate emissions (lb/million Btu) (b)
Plant LL Boiler #19	69 (236)	VS	4.8 (19.3)	73	2.6	11.4	0.10
Plant LL Boiler #20	69 (236)	VS	4.3 (17.3)	85-91	2.5	10.4	0.07
Plant AAA	37 (125)	MVT	1.9 (7.5)	92	1.3	4.4	0.08

(a) VS = Venturi scrubber, MVT = multiventuri tray scrubber.
(b) Multiply lb/million Btu by 430 for conversion to ng/J.

TABLE 4-3. PM EMISSIONS DATA FOR FABRIC FILTERS APPLIED TO COAL-FIRED BOILERS (19)

Plant	Boiler capacity, MW (million Btu/hr) heat input	Fuel			Test load range (percent of design capacity)	Boiler type (b)	Controlled particulate emissions (lb/million Btu) (c)	Air/cloth ratio (ACFM/sq ft)	
		percent ash	percent sulfur	heating value (Btu/lb) (a)				design	actual
DuPont (EE-2)	19 (64)	6.9	2.8	13,600	98-100	SS	0.015	3.4	3.4
Formica (J2-4)	19 (65)	6.9	0.8	NA (d)	84-96	SS	0.033	2.5	2.3
DuPont (EE-4)	37 (125)	7.0	2.6	13,500	77-78	SS	0.010	3.7	2.9
DuPont (EE-5)	45 (181)	6.5	2.9	13,800	96	SS	0.028	3.7	3.6
SOHIO	33 (115)	12.3	3.6	11,900	71	FBC	0.019	NA	NA
World Carpets	13 (48)	8.3	0.6	13,700	74	SS	0.016	NA	NA
California Portland	59 (208)	8.8	0.4	12,200	99	CFB	0.035	NA	NA

(a) Multiply Btu/lb by 2.323 for conversion to kJ/kg.
(b) SS = Spreader stoker, FBC = Fluidized bed combustor, CFB = Circulating fluidized bed combustor.
(c) Multiply lb/million Btu by 430 for conversion to ng/J.
(d) NA = Not available.

the four coal-fired spreader stoker boilers, the fabric filters were operated with air-to-cloth (A/C) ratios of 0.7 to 1.1 meters per minute (m/min) (2.3 to 3.6 feet per minute [ft/min]). Coal ash contents for all the boilers ranged from 6.5 to 12.3 weight percent.

The boiler design types included in Table 4-3 are spreader stoker boilers, a bubbling bed FBC unit, and a circulating bed FBC unit. Boiler sizes range from 13 to 59 MW (48 to 208 million Btu/hour). Fabric filters reduced PM emissions from each of these boilers to less than 22 ng/J (0.05 lb/million Btu). These data indicate that fabric filter performance is not significantly affected by boiler design type or size. Thus, fabric filters are considered to be a demonstrated control technique for reducing PM emissions from small coal-fired boilers to 22 ng/J (0.05 lb/million Btu) or less.

4.6 ELECTROSTATIC PRECIPITATORS

Table 4-4 presents PM emission test data from ESPs on coal-fired boilers ranging from 27 to 110 MW (92 to 375 million Btu/hour) in size. As discussed in Section 3.4, ESP performance is primarily dependent on SCA; thus, these data are also representative of ESPs applied on small coal-fired boilers. The ash content of the coals burned ranged from 5.4 to 12.0 weight percent. All tests were conducted using EPA Method 5 and resulted in PM emissions ranging from 3 to 19 ng/J (0.006 to 0.044 lb/million Btu).

Four tests were conducted on cold-side ESPs (i.e., located downstream of the air preheater) and two tests were performed on a hot-side ESP (i.e., located upstream of the air preheater). Operating SCAs of the cold-side ESPs ranged from 419 to 1,300 $m^2/1{,}000\ m^3/s$ (128 to 397 $ft^2/1{,}000$ acfm); the hot-side ESP operated at SCAs of 1,770 and 2,080 $m^2/1{,}000\ m^3/s$ (542 and 634 $ft^2/1{,}000$ acfm).

All the emission tests shown in Table 4-4 were conducted on boilers firing coals with sulfur contents of 1.0 weight percent sulfur or less, except for the Monsanto K7 boiler. A larger collection area is generally required to achieve a given PM collection efficiency on low sulfur coal-fired units than on high sulfur coal-fired units.[21] Thus, the emission control levels shown in Table 4-4 would be achievable on boilers firing high

TABLE 4-4. PM EMISSIONS DATA FOR ELECTROSTATIC PRECIPITATORS APPLIED TO COAL-FIRED BOILERS (19)

Plant	Boiler capacity, MW (million Btu/hr) heat input	Fuel			Test load range (percent of design capacity)	Boiler type (b)	Controlled particulate emissions (lb/million Btu) (c)	Specific collection area (sq ft/1000 ACFM) (d)	
		percent ash	percent sulfur	heating value (Btu/lb) (a)				design	operating
Monsanto (K-7)	27 (92)	12.0	NA (e)	12,500	103-106	SS	0.007	132	128
Monsanto (K-8)	35 (120)	11.2	1.00	12,500	93-98	SS	0.006	156	160
Monsanto (K-9)	46 (156)	11.4	0.57	11,400	99-102	SS	0.012	128	128
KVB Plant P	73 (250)	6.6	0.73	13,100	87-89	SS	0.021	349	397
KVB Plant N (f)	110 (375)	8.3	0.54	10,200	76	SS	0.044	344	542
KVB Plant N (f)	110 (375)	5.4	0.63	10,600	52-59	SS	0.018	344	634

(a) Multiply Btu/lb by 2.323 for conversion to kJ/kg.
(b) SS = Spreader stoker.
(c) Multiply lb/million Btu by 430 for conversion to ng/J.
(d) Multiply sq ft/1000 ACFM by 3.2729 for conversion to square meters per 1000 cubic meters per second.
(e) NA = Not available.
(f) All tests done on a hot side ESP.

sulfur coal with SCAs equal to or less than those shown.

The emission tests indicate that a cold-side ESP with an SCA of at least 1,310 m^2/1,000 m^3/s (400 ft^2/1,000 acfm) is capable of achieving PM emission levels ranging from 3 to 19 ng/J (0.006 to 0.044 lb/million Btu) on small boilers firing low sulfur coal. A hot-side ESP with an SCA of at least 2,090 m^2/1,000 m^3/s (640 ft^2/1,000 acfm) could achieve emission levels ranging from 7 to 19 ng/J (0.018 to 0.044 lb/million Btu) on small boilers firing low sulfur coal. Therefore, ESPs are considered to be a demonstrated control technique for reducing PM emissions from coal-fired boilers to 22 ng/J (0.05 lb/million Btu) or less.

4.7 ALTERNATIVE CONTROL LEVELS

As discussed above, in some cases alternative control levels selected for standards limiting SO_2 emissions from small coal-fired boilers will also result in PM emission reductions. Consequently, alternative control levels considered for standards limiting PM emissions should be discussed in relation to alternative control levels for SO_2 standards.

Alternative Control Level 1 for standards limiting SO_2 emissions from small coal-fired boilers is 520 ng/J (1.2 lb/million Btu) and is based on the use of low sulfur coal. Alternative control levels for SO_2 standards based on the use of low sulfur coal will not affect PM emissions. Thus, the PM emission levels associated with SO_2 Alternative Control Level 1 are the PM regulatory baseline emission level of 190 ng/J (0.45 lb/million Btu) for boilers of less than 8.7 MW (30 million Btu/hour) and 260 ng/J (0.60 lb/million Btu) for boilers of 8.7 MW (30 million Btu/hour) or greater.

Particulate matter emissions could be reduced to 130 ng/J (0.30 lb/million Btu) or less for small coal-fired boilers using a double mechanical collector. Emissions could also be reduced to 86 ng/J (0.20 lb/million Btu) or less by using a sidestream separator or to 43 ng/J (0.10 lb/million Btu) or less by using a wet scrubber. Particulate matter emissions could be further reduced to a 22 ng/J (0.05 lb/million Btu) or less by use of a fabric filter or an ESP.

Alternative Control Level 2 for standards limiting SO_2 emissions from small coal-fired boilers is a 90 percent reduction is SO_2 emissions on a

continuous basis. This level can be met by use of FGD or FBC systems. As discussed in Section 4.4, use of wet FGD systems will reduce PM emissions to 43 ng/J (0.10 lb/million Btu) or less. Particulate matter emissions can be further reduced to 22 ng/J (0.05 lb/ million Btu) by installing a fabric filter or an ESP upstream of the FGD system.

Fluidized bed combustion units and lime spray dryers are almost always designed with a fabric filter for PM control. Therefore, if an FBC unit or lime spray dryer is used to meet SO_2 Alternative Control Level 2, PM emissions will be reduced to 22 ng/J (0.05 lb/million Btu) or less.

An emission rate of 130 ng/J (0.30 lb/million Btu) is selected as Alternative Control Level A for standards limiting PM emissions from small coal-fired boilers. This alternative is based on the use of a double mechanical collector.

Similarly, emission rates of 86 ng/J (0.20 lb/million Btu) and 43 ng/J (0.10 lb/million Btu) are selected as Alternative Control Levels B and C. Alternative B is based on the use of a sidestream separator and Alternative C is based on the use of a wet scrubber.

These alternatives would impose additional emission control requirements under Alternative Control Level 1 for SO_2 standards. They would, however, impose no additional emission control requirements under Alternative Control Level 2.

Finally, an emission rate of 22 ng/J (0.05 lb/million Btu) is selected as Alternative Control Level D for standards limiting PM emissions from small coal-fired boilers. This alternative is based on the use of an ESP or a fabric filter.

As with Alternatives A, B, and C, Alternative D would impose additional emission control requirements under Alternative Control Level 1 for SO_2 standards. Unlike these other alternatives, however, it would also impose additional emission control requirements under Alternative Control Level 2 for SO_2 standards if a wet FGD system were used to meet the 90 percent SO_2 reduction requirement. If, on the other hand, an FBC unit or a lime spray dryer was used to meet the 90 percent SO_2 reduction requirement associated with Alternative Control Level 2, this alternative for PM emissions would also impose no additional emission control requirements.

5.0 WOOD PM EMISSIONS AND CONTROL TECHNIQUES

Wood, unlike oil and coal, contains little or no sulfur. In addition, few, if any, mixed fuel-fired (i.e., coal/wood or oil/wood) boilers are expected for this source category.[22] As a result, there is no need to consider levels selected for SO_2 standards in considering alternative control levels for PM emissions from small wood-fired boilers. The control techniques considered for limiting PM emissions from small wood-fired boilers include double mechanical collectors, wet scrubbers, and ESPs. Fabric filters were not considered because of the potential fire hazards associated with wood-firing applications.

5.1 REGULATORY BASELINE EMISSION LEVEL

The national SIP emission limits for PM emissions from small wood-fired boilers range from 160 to 170 ng/J (0.37 to 0.40 lb/million Btu).[23] The PM control system generally used to meet these emission limits is a single mechanical collector. However, as with single mechanical collectors on coal-fired boilers, single mechanical collectors on wood-fired boilers are unable to maintain these low emission levels over time. Mechanical collector performance deteriorates with time and PM emissions increase. Thus, the regulatory baseline for small wood-fired boilers is selected to be 190 ng/J (0.45 lb/million Btu) for boilers smaller than 8.7 MW (30 million Btu/hr) and 260 ng/J (0.60 lb/million Btu) for boilers greater than or equal to 8.7 MW (30 million Btu/hr) to reflect single mechanical collector performance on small wood-fired boilers over time.

5.2 DOUBLE MECHANICAL COLLECTORS

As discussed above in Section 4.2 for coal-fired boilers, double mechanical collectors will also reduce PM emissions from wood combustors. However, they are relatively ineffective for PM_{10} removal. These particles are in the inhalable range and have the greatest potential for adverse health impacts.

To assess the performance of double mechanical collectors on wood-fired boilers, PM emission data from four sites were reviewed.[24] The data represent four compliance tests conducted using Reference Method 5 procedures. The boilers ranged in size from 7.3 to 44 MW (25 to 150 million Btu/hour) and were operated at 72 to 116 percent of full load during the tests. Outlet PM emissions ranged from 35 to 92 ng/J (0.082 to 0.215 lb/million Btu).

These double mechanical collectors were tested at relatively high boiler loads. Mechanical collectors, in general, are not as effective at low load conditions. Thus, as with coal-fired boilers, double mechanical collectors are considered to be a demonstrated control technique for reducing PM emissions from small wood-fired boilers to 130 ng/J (0.30 lb/million Btu) or less.

5.3 WET SCRUBBERS

Table 5-1 presents PM emissions data from wood-fired boilers equipped with wet scrubbers. Particulate emissions range from 21 to 91 ng/J (0.048 to 0.212 lb/million Btu). All boilers shown are spreader stokers which range in size from 16 to 67 MW (55 to 230 million Btu/hr). The PM control systems consist of a mechanical collector followed by a wet scrubber. The boilers were operated at loads ranging from 47 to 103 percent of full load during the tests. Fly ash reinjection is employed at all sources except at boilers AC1 and AC2. All data were obtained using EPA Method 5.

The data show that wet scrubbers operating at low pressure drops [0.4 to 3.4 KPa (1.5 to 13.5 inches water)] and preceded by a mechanical collector can reduce PM emissions to 86 ng/J (0.20 lb/million Btu) or less. Wet scrubbers operating at medium pressure drops [(3.8 to 6.0 KPa (15 to 26 inches water)] and preceded by a mechanical collector can reduce PM emissions to 43 ng/J (0.10 lb/million Btu) or less. Therefore, low pressures drop wet scrubbers are considered demonstrated at 86 ng/J (0.20 lb/million), whereas medium pressure drop wet scrubbers are considered demonstrated at 43 ng/J (0.10 lb/million Btu).

TABLE 5-1. PM EMISSIONS DATA FOR WET SCRUBBERS APPLIED TO WOOD-FIRED BOILERS (25)

Plant	Number of units	Boiler capacity, MW (million Btu/hr) heat input	Scrubber type	Efficiency (%)	Fuel sulfur (wt. %)	Fuel ash (wt. %)	Test load (percent of design capacity) (a)	Average operating pressure drop (inches water) (b)	Controlled particulate emissions (lb/million Btu) (c)
Champion International (AB2)	1	32 (108)	Imp	NA	NA	NA	79	6-8	0.068
Georgia Pacific (AC1)	2	17/17 (57/57) (d)	Imp	NA	NA	NA	63	6-8	0.182
Georgia Pacific (AC2)	1	16 (55)	Imp	NA	NA	NA	47	6-8	0.170
Georgia Pacific (AD1)	1	18 (61)	Ven	NA	NA	NA	73 (e)	6-8	0.182
Georgia Pacific (AG1)	1	50 (170)	Ven	NA	NA	NA	103	6-8	0.169
Georgia Pacific (AI1)	1	50 (170)	Ven	NA	NA	NA	86	6-8	0.212
Georgia Pacific (AF1)	1	54 (185)	Imp	NA	NA	NA	72	6-8	0.100
Georgia Pacific (AE1)	1	54 (185)	Ven	NA	NA	NA	85	6-8	0.131
Georgia Pacific (AH1)	1	63 (215)	Ven	NA	NA	NA	65	6-8	0.148
St. Joe Paper (AJ2) (f)	1	50 (170)	VTV	94	0.03	2.2	91	8	0.104
St. Joe Paper (AJ4) (f)	1	50 (170)	VTV	96	0.01	1.9	95	13.5	0.137
St. Joe Paper (AJ5) (f)	1	50 (170)	VTV	NA	NA	NA	91	15.2	0.057
Boise Cascade (AA1)	1	67 (230)	VTV	NA	NA	2-8 (g)	95	18	0.048
St. Regis Paper (AK2) (f)	1	61 (210)	Ven	98	0.04	1.7	94	20	0.074
St. Regis Paper (AK3) (f)	1	61 (210)	Ven	NA	0.17	4.2	100	26	0.063

NA = Not available.
Imp = Impingement
Ven = Venturi
VTV = Variable Throat Venturi

(a) Average value during testing.
(b) Multiply inches of water by 0.2486 for conversion to kPa.
(c) Multiply lb/million Btu by 430 for conversion to ng/J.
(d) Two boilers which exhaust into a single wet scrubber.
(e) Estimated, based on mass emission rate and F-factor.
(f) EPA Method 5 data acquired on EPA tests.
(g) These data did not come from an analysis done during emission testing. They were obtained from industry sources and are representative of the typical fuel burned at this facility.

5.4 ELECTROSTATIC PRECIPITATORS

Table 5-2 presents PM emission test data for ESPs applied on wood-fired boilers that range in size from 50 to 202 MW (170 to 690 million Btu/hour). As discussed above for oil and coal combustion, ESP performance on large wood-fired boilers is also representative of ESP performance on small wood-fired boilers. All boilers are spreader stokers firing wood or wood/coal mixtures. The boilers operated at 25 to 69 percent of full load during the tests. A mechanical collector is located upstream of each ESP; fly ash reinjection was used during all tests. The PM emission test results ranged from 18 to 31 ng/J (0.042 to 0.072 lb/million Btu). The operating SCAs ranged from 752 to 1,480 m^2/1,000 m^3/s (230 to 453 ft^2/1,000 acfm).

The emission test data indicate that an ESP with an SCA of at least 980 m^2/1,000 acfm) and preceded by a mechanical collector is capable of achieving a PM emission level of 43 ng/J (0.10 lb/million Btu) heat input or less on small wood-fired boilers. Therefore, ESPs are considered to be a demonstrated control technique for reducing PM emissions from wood-fired boilers to 43 ng/J (0.10 lb/million Btu) heat input or less.

5.5 ALTERNATIVE CONTROL LEVELS

Alternative Control Level A for wood-fired boilers is selected as 130 ng/J (0.30 lb/million Btu) heat input based on the use of a double mechanical collector. Alternative Control Level B is selected as 86 ng/J (0.20 lb/million Btu) heat input, which can be met by using a wet scrubber operated at a low pressure drop and preceded by a mechanical collector. Finally, Alternative Control Level C for wood-fired boilers is selected as 43 ng/J (0.10 lb/million Btu) heat input. This level can be achieved by using a mechanical collector combined with either an ESP or a wet scrubber operated at a medium pressure drop.

TABLE 5-2. SUMMARY OF PARTICULATE EMISSION TEST DATA ON WOOD-FIRED BOILERS CONTROLLED WITH ESPS AND EGBS (23)

Plant	Control device	Boiler capacity, MW (million Btu/hr) heat input	Fuel			Test load range (percent of design capacity)	Boiler type	Specific collection area (sq ft/1000 ACFM) (b)		Controlled particulate emissions (lb/million Btu) (c)
			% ash	% sulfur	heating value (Btu/lb) (a)			design	operating	
Champion International Coop (BA1)	ESP	50 (170)	NA	NA	NA	66	SS	177	230	0.072
Westvaco Bleached Board (BI1) (d)	ESP	108/147 (370/500)	3.4 (e)	0.3	10,750	25/25	SS	296	320	0.042
Westvaco Bleached Board (BB1)	ESP	202 (690)	4.8 (f)	NA	8,250	69	SS	298	453	0.057
Weyerhaeuser Co. (BE2) (g)	EGB	180 (615)	9.4 (h)	0.06	8,270	96	SS	NA	6.0 (j)	0.027
Weyerhaeuser Co. (BE3) (i)	EGB	180 (615)	3.8	NA	8,970	101	SS	NA	3.4 (j)	0.025
Weyerhaeuser Co. (BE4) (i)	EGB	180 (615)	3.8	NA	8,910	116	SS	NA	4.0 (j)	0.024
Weyerhaeuser Co. (BE5) (i)	EGB	180 (615)	4.8	NA	8,780	95	SS	NA	5.6 (j)	0.039
Weyerhaeuser Co. (BE6) (i)	EGB	180 (615)	4.8	NA	8,830	107	SS	NA	7.1 (j)	0.051

(a) Multiply Btu/lb by 2.323 for conversion to kJ/kg.

(b) Multiply sq ft/1000 ACFM by 3.2729 for conversion to sq meters per 1000 cubic meters per second.

(c) Multiply lb/million Btu by 430 for conversion to ng/J.

(d) The flue gas from two boilers pass through individual mechanical collectors. It is then combined into a single duct and split to enter a two-chamber ESP with two stacks. The test data and emission levels shown are the weighted average of both stacks.

(e) Boiler burns low sulfur coal with the wood. The analysis of the coal showed the following composition: moisture - 5.5%; ash (dry) - 12.4%; sulfur (dry) - 0.86%.

(f) These data did not come from an analysis done during emission testing. They were obtained from industry sources and are representative of the typical fuel burned at this facility.

(g) The EGB has three modules, each of which cleans one-third of the flue gas. Each module has a separate stack. The emission levels shown are the weighted average of all three stacks.

(h) At this facility, char from the first stage of the mechanical collector is slurried and separated by screens into large and small fractions. The large char is mixed with the hog fuel. These values represent an analysis of the mixture of char and hog fuel.

(i) Emissions are from the outlet of module 3 of the EGB.

(j) For EGB, this value is pressure drop in inches of water. Multiply inches of water by 0.2468 for conversion to kPa.

NA = not available.

SS = Spreader Stoker.

ESP = Electrostatic Precipitator.

EGB = Electrostatic Gravel Bed Filter.

6.0 REFERENCES

1. U.S. Environmental Protection Agency. Small Steam Generating Unit Characteristics and Emission Control Techniques. Research Triangle Park, NC. March 31, 1989.

2. U.S. Environmental Protection Agency. Nonfossil Fuel-Fired Industrial Boilers - Background Information. Research Triangle Park, NC. Publication No. EPA-450/3-82-007. March 1982.

3. U.S. Environmental Protection Agency. Fossil Fuel-Fired Industrial Boilers - Background Information. Volume I. Research Triangle Park, NC. Publication No. EPA-450/3-82-006a. March 1982.

4. Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Sulfur Dioxide (SO_2) Emission Standards for Small Steam Generating Units. U.S. Environmental Protection Agency, Research Triangle Park, NC. EPA Publication No. EPA-450/3-89-12. May 1989.

5. Particulate Matter Emission from Residual Oil-Fired Boilers. Prepared by Radian Corporation. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, NC. June 4, 1984. p. 2.

6. Reference 5. p. 9.

7. Reference 1.

8. Reference 4. p. 4.

9. U.S. Environmental Protection Agency. Compilation of Air Pollution Emission Factors. AP-42 Supplement No. 13. Research Triangle Park, NC. August 1982.

10. GCA Corporation. Particulate Emission Control Systems for Oil-Fired Boilers. Prepared for the U. S. Environmental Protection Agency, Research Triangle Park, NC. Publication No. 450/3-74-063, December, 1974. pp. 68-74.

11. Reference 10.

12. Reference 1.

13. Reference 3. p. 4-43.

14. Reference 1.

15. Telecon. Aul, E.F. (Radian Corporation), with Berst, A. (Zurn, Air Systems Division), December 8, 1987. Costs for regular inspection and maintenance programs for mechanical collectors and sidestream separators.

16. Memorandum from Waddell, J.T., and E.F. Aul, Radian Corporation, to Maxwell, W.H., EPA/ISB. January 15, 1988. Performance of Dual Mechanical Collectors on Small Coal- and Wood-Fired Boilers.

17. Reference 1.

18. U.S. Environmental Protection Agency. Fossil Fuel-Fired Industrial Boilers - Background Information. Volume 2. Research Triangle Park, NC. Publication No. EPA-450/3-82-006b. March 1982. pp. C-111, C-114, C-115 and C-137.

19. Reference 1.

20. Reference 1.

21. Reference 3. p. 4-45.

22. Memorandum. Aul, E.F., Radian Corporation, to Maxwell, W.H. EPA/ISB. September 22, 1987. Population Projection for Small Mixed Fuel-Fired Steam Generating Units. 15 p.

23. Reference 1.

24. Memorandum from Frey, H.C. and J.T. Waddell, Radian Corporation, to Copland, R.A. EPA/SDB. February 28, 1989. State Permitting Practices for Particulate Matter Emissions from Small Coal- and Wood-Fired Boilers. 30 p.

25. Reference 1.

26. Reference 1.